

SASOL CHEMICALS (USA), LLC**2020 HWDIR EXEMPTION PETITION REISSUANCE REQUEST****MASTER TABLE OF CONTENTS**

SECTION 1.0**SITE INFORMATION**

1.0 Administrative Information	1-1
EXECUTIVE SUMMARY	1-1
1.1 Regulatory Classification	1-5
1.2 Site Description	1-10
1.2.1 General Identification Data	1-10
1.2.2 Adjacent Landowners and Mineral Owners	1-10
1.2.3 Minerals Rights Owners	1-11
1.2.4 Nature and Status of Well Activity	1-11
1.2.5 Facility Nomenclature	1-11
1.2.6 Regulatory Intervals	1-12
1.3 Well Data – Plant Well No. 1 (WDW147)	1-13
1.3.1 Well Location - Plant Well No. 1 (WDW147)	1-13
1.3.2 Injection Program - Plant Well No. 1 (WDW147)	1-13
1.4 Well Data – Plant Well No. 2 (WDW319)	1-16
1.4.1 Well Location - Plant Well No. 2 (WDW319)	1-16
1.4.2 Injection Program - Plant Well No. 2 (WDW319)	1-16
1.5 Petition Quality Assurance/Quality Control (QA/QC)	1-19
1.5.1 Overview	1-19

1.5.2	Background	1-21
1.5.3	Project Task Description	1-28
1.5.4	Quality Objectives and Criteria	1-33
1.5.5	Data Generation and Acquisition	1-35
1.5.6	Document Control	1-47
1.5.7	Data Validation and Usability	1-49
REFERENCES.....		1-53

SECTION 2.0

SITE GEOLOGY

2.0	Site Geology	2-1
2.1	Introduction	2-1
2.2	Regional Geology	2-2
2.2.1	Regional Stratigraphy	2-4
2.2.2	Regional Hydrostratigraphy	2-12
2.2.3	Regional Structure	2-13
2.2.4	Seismicity	2-14
2.3	Local Geology	2-25
2.3.1	Local Stratigraphy	2-5
2.3.2	Stratigraphy of Confining Zones, Injection Zone, and Injection Intervals	2-26
2.3.3	Local Structure	2-37
2.3.4	Fault Transmissivity	2-42
2.4	Oil and Gas Operations	2-58
2.5	Hydrogeology	2-59

2.6	Hydrogeologic Compatibility	2-61
2.6.1	Waste Stream - Injection Interval Compatibility	2-61
2.6.2	Waste Stream - Aquiclude Layer Compatibility.....	2-63
2.7	Summary	2-67
REFERENCES.....		2-68

SECTION 3.0

FLOW AND CONTAINMENT MODELING

3.0	Flow and Containment Modeling	3-1 3
3.1	Summary	3-1
3.2	Introduction.....	3-2
3.3	Description of the Models.....	3-4
3.3.1	The DuPont Basic Plume Model.....	3-5
3.3.2	The DuPont Multilayer Pressure Model	3-5
3.3.3	The DuPont Multilayer Vertical Permeation Model.....	3-5
3.3.4	The DuPont Molecular Diffusion Model	3-6
3.3.5	The DuPont 10,000-Year Waste Plume Model	3-8
3.4	Model Input Data and Sources	3-11
3.4.1	Location	3-11
3.4.2	Local and Regional Geology	3-12
3.4.3	Geologic Inputs to the Model	3-13
3.4.4	Layer Thickness	3-15
3.4.5	Transmissibility and Mobility.....	3-17
3.4.5.1	Layer Transmissibility in the DuPont Multilayer Pressure Model.....	3-18

3.4.5.2	Layer Mobility in the DuPont 10,000-Year Waste Plume Model	3-19
3.4.5.3	Aquiclude (confining shale) Layer Permeability.....	3-20
3.4.6	Porosity	3-21
3.4.6.1	Aquiclude (confining shale) Layer Porosity.....	3-21
3.4.7	Original Formation Pressure	3-24
3.4.8	Compressibility	3-25
3.4.8.1	Confining Shale Layer Compressibility	3-32
3.4.9	Temperature, Total Dissolved Solids, Viscosity, and Specific Gravity	3-32
3.4.9.1	Temperature	3-32
3.4.9.2	Viscosity	3-33
3.4.9.3	Specific Gravity	3-35
3.4.10	Layer Dispersion Characteristics	3-38
3.4.10.1	Field Scale Dispersivities in DuPont 10,00-Year Waste Plume Model.....	3-39
3.4.10.2	Multiplying Factor for Advective Dispersion in DuPont Basic Plume Model	3-40
3.4.11	Waste Stream Characteristics	3-44
3.4.11.1	Free Water Diffusion Coefficients.....	3-47
3.4.11.2	Effective Diffusion Coefficients	3-49
3.4.11.3	Concentration Reduction Factors.....	3-50
3.4.12	Formation Characteristics	3-51
3.4.12.1	Formation Dip Angle	3-51
3.4.12.2	Formation Fluid Background Velocity	3-53
3.4.13	Boundary Conditions	3-54
3.4.13.1	Renee-Lynchburg Fault Boundaries	3-54
3.4.13.2	Clinton Dome Boundaries	3-55

3.4.13.2.1 Clinton Dome Boundaries – Case 1 Models	3-56
3.4.13.2.2 Clinton Dome Boundaries – Case 2 Models	3-59
3.4.13.3 Potential Sand Shale-out Boundaries.....	3-59
3.4.13.3.1 Frio B Sand	3-59
3.4.14 Waste Disposal History.....	3-60
3.5 Model Strategy – Operational and 10,000-Year Models	3-68
3.5.1 Model Strategy - Operational Pressure Model.....	3-68
3.5.2 Model Strategy - Operational Plume Model.....	3-71
3.5.3 Model Strategy - Vertical Permeation Model	3-74
3.5.4 Model Strategy - 10,000-Year Vertical Model	3-74
3.5.5 Model Strategy - 10,000-Year Plume Model.....	3-74
3.5.5.1 Model Strategy – 10,000-Year Plume Model Computation Grid Area.....	3-77
3.6 Model Calibration with Historic Data.....	3-78
3.6.1 Model Calibrations with Formation Pressure - Frio A/B/C Injection Interval	3-80
3.6.1.1 Calibration Results, Case 1 – Sealed Fault A Model Case.....	3-80
3.6.1.2 Calibration Results, Case 2 – Open Fault Model Case.....	3-82
3.6.1.3 Static Calibration Results at Exxon Mobil	3-83
3.6.2 Model Calibrations with Formation Pressure - Frio E&F Injection Interval	3-84
3.6.2.1 Calibration Results, Case 1 – Sealed Fault A Model Case.....	3-84
3.6.2.2 Calibration Results, Case 2 – Open Fault Model Case.....	3-85
3.6.2.3 Static Calibration Results at Exxon Mobil	3-87
3.7 Model Results	3-88
3.7.1 Current and Near Future Waste Distribution	3-88
3.7.1.1 Horizontal Extent.....	3-88

3.7.1.1.1	Case 1 – Sealed Fault A Case Plume Models	3-88
3.7.1.1.2	Case 2 – Open Fault Case Plume Models.....	3-89
3.7.1.2	Vertical Extent.....	3-90
3.7.1.3	Pressure Distribution within the Area of Review	3-90
3.7.1.3.1	DuPont Multilayer Pressure Model Run Files	3-93
3.7.1.3.2	Case 1 – Operational Pressure Buildup – Frio A/B/C Injection Interval...	3-93
3.7.1.3.3	Case 1 – Operational Pressure Buildup – Frio E&F Injection Interval.....	3-94
3.7.1.3.4	Case 2 – Operational Pressure Buildup – Frio A/B/C Injection Interval...	3-95
3.7.1.3.5	Case 2 – Operational Pressure Buildup – Frio E&F Injection Interval.....	3-96
3.7.1.3.6	DuPont Multilayer Pressure Model Summary.....	3-97
3.7.2	Post-Injection Waste Distribution.....	3-97
3.7.2.1	Pressure Recovery	3-97
3.7.2.2	Vertical Extent.....	3-98
3.7.2.3	Horizontal Extent.....	3-101
3.7.2.3.1	Horizontal Extent – Low Specific Gravity Plume	3-103
3.7.2.3.2	Horizontal Extent – High Specific Gravity Plume.....	3-104
3.7.2.3.3	Horizontal Extent – Composite Plume.....	3-115
3.7.2.3.4	Presentation of Long-term Plumes on Geology Maps.....	3-116
3.8	Sensitivity Analysis	3-117
3.9	Summary of Results	3-118
REFERENCES.....		3-120

SECTION 4.0

AREA OF REVIEW

4.0	Area of Review	4- 1
4.1	Summary	4-1
4.2	Introduction.....	4-4
4.3	Determination of the Area of Review	4-6
4.4	Artificial Penetrations in the Area of Review	4-11
4.4.1	2.5 - Mile Area of Review	4-11
4.4.2	Incomplete Records	4-11
4.4.3	Well Type.....	4-14
4.4.4	Rock Type	4-17
4.4.5	Drilling Methods and the Static Mud Column.....	4-19
4.4.6	Confining/Injection Zone Penetration.....	4-24
4.4.7	Extended Area of Review - Operational Plume.....	4-24
4.4.8	Extended Waste Plume Track	4-25
4.4.8.1	Extended Waste Plume Track - High Specific Gravity Plume.....	4-26
4.4.8.1	Extended Waste Plume Track - Low Specific Gravity Plume	4-27
4.5	Modeling Artificial Penetrations for Non-Endangerment	4-29
4.6	Modeling Wells Requiring Further Evaluation – No Migrations	4-35
REFERENCES.....		4-40

SECTION 5.0**WELL CONSTRUCTION**

5.0 WELL CONSTRUCTION.....	5-1
5.1 Plant Well No. 1 (WDW147).....	5-2
5.1.1 Drilling.....	5-2
5.1.2 Well Design and Construction.....	5-2
5.1.3 Original Completion	5-3
5.1.4 Current Completion	5-4
5.1.5 Well History - Plant Well No. 1.....	5-4
5.2 Plant Well No. 2 (WDW319).....	5-2
5.2.1 Drilling.....	5-10
5.2.2 Well Design and Construction.....	5-10
5.2.3 Original Completion	5-12
5.2.4 Current Completion	5-12
5.2.5 Well History - Plant Well No. 2.....	5-13
5.3 Well Materials Compatibillity	5-18
5.3.1 Corrosion Introduction.....	5-18
5.3.2 Types of Corrosion	5-18
5.3.3 Factors Influencing Corrosiveness of Injection Well Environments.....	5-19
5.3.4 Corrosion Detection Measurements.....	5-21
5.3.5 Corrosion Control	5-22
5.3.6 Corrosion and Hazardous Injection Fluids	5-22
5.3.7 Compatobility Testing	5-23
REFERENCES.....	5-25

SECTION 6.0

WASTEWATER DESCRIPTION AND PETITION IMPLEMENTATION AND COMPLIANCE

6.0 WASTWASTE DESCRIPTION AND COMPLIANCE	6-1
6.1 Wastewater Characterization	6-1
6.1.1 Regulatory Characterization of the Wastewater Streams	6-1
6.1.2 Current Sources of Injected Wastewater.....	6-3
6.1.3 Hazardous Wastes Subject to Federal Land Ban Restrictions	6-3
6.1.4 Hazardous Wastes Not Subject to Federal Land Ban Restrictions	6-4
6.1.5 Waste Stream pH and Maximum Specific Gravity.....	6-6
6.1.6 Maximum Monthly Volume	6-7
6.1.7 Average and Maximum Rates of Injection	6-7
6.1.8 Patterns of Injection	6-8
6.1.9 Injection Well Checklist	6-8
6.2 Waste Managment.....	6-9
6.2.1 Active Class I Injection Well Summary	6-9
6.2.2 Injected Waste Summary	6-9
6.2.3 Containment of Hazardous Waste in the Injection Zone	6-10
6.3 Implementation and Compliance	6-11
6.3.1 Storage Wastewater Flow, Collection and Storage.....	6-11
6.3.2 Monthly Injection Volume Compliance	6-12
6.3.3 Flow Allocation Implementation and Compliance	6-13
6.3.4 Specific Gravity Implementation and Compliance.....	6-14

6.3.4.1	Specific Gravity Measurment and Calculation.....	6-14
6.3.4.2	Cumulative Low Specific Gravity Waste Volume Limitation	6-15
6.3.5	Annual Presure Monitoring and Compliance	6-15
6.3.6	Injection Interval Pressure Buildup Compliance	6-16
6.3.7	Injection Interval Transmissivity and Mobility Implementation and Compliance	6-16
6.3.8	Injected Constituent Implementation and Compliance.....	6-16

SECTION 7.0

MECHANICAL INTEGRITY TESTING

7.0	Mechanic Integrity Testing	7-1
7.1	Introduction	7-1
7.2	Plant Well 1 (WDW147).....	7-2
7.2.1	Mechanical Integrity Test	7-2
7.3	Plant Well 2 (WDW319)	7-4
7.3.1	Mechanical Integrity Test	7-4
7.5	Summary	7-6
REFERENCES.....		7-7

MASTER LIST OF FIGURES

Figure 1-1	Location Map for the Sasol Chemicals (USA), LLC Greens Bayou Plant
Figure 1-2	Topographic Location Map
Figure 1-3	Relative locations of Plant Well No. 2 (WDW319) to Plant Well No. 1 (WDW147)
Figure 1-4	Type Log with Regulatory Intervals for Plant Well No. 1 (WDW147)
Figure 1-5	Type Log with Regulatory Intervals for Plant Well No. 2 (WDW319)
Figure 2-1	Stratigraphic Column of the Texas Gulf Coast
Figure 2-2	Schematic Northwest-Southeast Cross Sections Showing Evolutionary Stages in the Formation of the Northern Gulf of Mexico and East Texas Basin (from Jackson and Galloway, 1984)
Figure 2-3	Distribution of Cretaceous and Cenozoic Continental Margins in the Northwestern Gulf of Mexico (from Jackson and Galloway, 1984)
Figure 2-4	Geology Map of Texas
Figure 2-5	Frio Depositional Systems (from Galloway et al., 1982)
Figure 2-6	Sandstone Composition - Frio Formation of the Texas Gulf Coast (from Bebout et al., 1978)
Figure 2-7	Principal Drainage Axes for the Chita-Corrigan Fluvial System (from Galloway et al., 1977)
Figure 2-8	Sandstone Composition - Catahoula Formation of the Texas Gulf Coast (from Ledger et al., 1984)
Figure 2-9	Lower Miocene Depositional Systems (from Galloway, 1985)
Figure 2-10a	Paleogeographic reconstruction of the maximum regressive episode represented by the middle Miocene (operational unit A). Map depicts the interpreted depositional systems immediately preceding the middle Miocene (<i>Textularia</i>

stapperi) relative rise in sea level and marine transgression (modified from Morton et al., 1988)

- Figure 2-10b Paleogeographic reconstruction of the maximum regressive episode represented by the upper Miocene (operational unit B). Map depicts the interpreted depositional systems immediately preceding the late Miocene (*Bigenerina A.*) relative rise in sea level and marine transgression (modified from Morton et al., 1988)
- Figure 2-11 Composite percent SS Map (from Morton et al., 1988)
- Figure 2-12 Major Aquifers within Texas
- Figure 2-13 Stratigraphic and Hydrologic Section C-C'
- Figure 2-14 Top of Frio (Injection Zone) Structure Map (modified from Galloway et al., 1982)
- Figure 2-15 Tectonic Features of Texas
- Figure 2-16 Regional NW-SE Structural/Stratigraphic Cross Sections 5-5' (Dodge & Posey, 1981)
- Figure 2-17 Regional NW-SE Structural/Stratigraphic Cross Sections 6-6' (Dodge & Posey, 1981)
- Figure 2-18 Regional NE-SW Structural/Stratigraphic Cross Section B'-B'' (Dodge & Posey, 1981)
- Figure 2-19 Regional NE-SW Structural/Stratigraphic Cross Section C'-C'' (Dodge & Posey, 1981)
- Figure 2-20 Seismic Risk Map (from USGS, 2014)
- Figure 2-21 Structure of a Gulf Coast Growth Fault (modified from Jackson and Galloway, 1984)
- Figure 2-22 Radial Faulting from Salt Structures Mapped on Top of the Frio Formation, from Port Arthur Area, Texas (from Jackson and Galloway, 1984)
- Figure 2-23 Cross Section Location Map

Figure 2-24	NW-SE Structural Cross Section
Figure 2-25	SW-NE Structural Cross Section
Figure 2-26	Structural Contour Map on the Anahuac Marker
Figure 2-27	Net Shale Isopach Map – Anahuac Formation Confining Zone
Figure 2-28	Structure Contour Map on the Vicksburg Marker
Figure 2-29	Gross Sand Isopach Map – Frio E&F Sand
Figure 2-30	Gross Sand Isopach Map – Frio A&B Sand
Figure 2-31	Gross Sand Isopach Map – Frio C Sand
Figure 2-32	Thickness of shale between the base of the Frio E&F Sand and the top of the Frio A&B Sand
Figure 2-33	Structure Contour Map on Top of the Frio E&F Sand
Figure 2-34	Surface Fault Pattern in the Houston Area
Figure 2-35	Fault seal and nonseal: (1) dragging of ductile clays into fault plane during faulting creates clay seal between two sandstones (A and B); (2) juxtaposition of reservoir to impermeable clay bed; and (3) sandstone-to-sandstone window or leak in fault plane creating possible spillpoint to migrating fluids (modified from Smith, 1980 and Downey, 1984)
Figure 2-36	Schematic cross section and pressure profile of the Akaso G reservoirs (from Jev et al., 1993)
Figure 2-37	Gulf Coast Gas Field Example – Cross-Fault Pressure Communication
Figure 2-38	2015 Chicot Potentiometric Levels Harris County (Kasmarek et al., 2015)
Figure 2-39	2015 Evangeline Potentiometric Levels Harris County (Kasmarek et al., 2015)
Figure 2-40	Structure Map - Base of USDW Structure Map (3-ohm-m Resistivity)
Figure 2-41	Variation of Total Dissolved Solids (TDS) at Sasol

- Figure 3-1 General map of Sasol Greens Bayou Plant and East Houston Area Class I Injection Wells
- Figure 3-2 Correlation of Lower Frio Sands at the Sasol Greens Bayou Plant
- Figure 3-3 Structural Cross Section – Houston Ship Channel Area – Class I Injection Wells
- Figure 3-4 Northwest-southeast Structural Cross Section from Sasol to the Houston Ship Channel Area Class I Injection Wells
- Figure 3-5 Type Log of the Frio E&F Sand Injection Interval and the Frio A&B Sand and the Frio C Sand Injection Interval in the DuPont Multilayer Pressure Model
- Figure 3-6 Temperature Profile with depth - Houston Area Injection Wells and Artificial Penetrations
- Figure 3-7 Nomograph of Viscosity of NaCl Brines Variation with Temperature (data from Petroleum Engineering Handbook, 1987)
- Figure 3-8 Daily and calculated three-whole month volume weighted injectate specific gravities at 20 °C reference temperature
- Figure 3-9 Rate of geologic dip northwest of the Sasol Greens Bayou Plant and dip rates employed in the long-term Low Specific Gravity Plume Model
- Figure 3-10 Cross Section C-C' from Baker (1979)
- Figure 3-11 Case 1 – Sealed Fault A-A' Case Model Boundary Conditions
- Figure 3-12 DuPont Basic Plume Model Streamlines for the Case 1 Frio A&B Sand and Frio C Sand Injection Interval Model
- Figure 3-13 DuPont Basic Plume Model Streamlines for the Case 1 Frio E&F Sand Injection Interval Model
- Figure 3-14 Case 2 – Open Case Transmissive Fault Model Set-up Boundary Conditions
- Figure 3-15 Flowing bottomhole pressure calibration for the Frio A/B/C Sand - Sealed Fault Case 1 at a reference depth of 6,820.5 feet bgl in Plant Well 2 (WDW319)
- Figure 3-16 Shut-in bottomhole pressure calibration for the Frio A/B/C Sand - Sealed Fault Case 1 at a reference depth of 6,820.5 feet bgl in Plant Well 2 (WDW319)

- Figure 3-17 Flowing bottomhole pressure calibration for the Frio A/B/C Sand - Open Fault Case 2 at a reference depth of 6,820.5 feet bgl in Plant Well 2 (WDW319)
- Figure 3-18 Shut-in bottomhole pressure calibration for the Frio A/B/C Sand - Open Fault Case 2 at a reference depth of 6,820.5 feet bgl in Plant Well 2 (WDW319)
- Figure 3-19 Flowing bottomhole pressure calibration for the Frio A/B/C Sand - Sealed Fault Case 1 at a reference depth of 6,820.5 feet bgl in ExxonMobil Wells
- Figure 3-20 Flowing bottomhole pressure calibration for the Frio A/B/C Sand - Open Fault Case 2 at a reference depth of 6,820.5 feet bgl in ExxonMobil Wells
- Figure 3-21 Flowing bottomhole pressure calibration for the Frio E and F Sand - Sealed Fault Case 1 at a reference depth of 6,548 feet bgl in Plant Well 1 (WDW147)
- Figure 3-22 Shut-in bottomhole pressure calibration for the Frio E and F Sand - Sealed Fault Case 1 at a reference depth of 6,548 feet bgl in Plant Well 1 (WDW147)
- Figure 3-23 Flowing bottomhole pressure calibration for the Frio E and F Sand - Open Fault Case 2 at a reference depth of 6,548 feet bgl in Plant Well 1 (WDW147)
- Figure 3-24 Shut-in bottomhole pressure calibration for the Frio E and F Sand - Sealed Fault Case 1 at a reference depth of 6,548 feet bgl in Plant Well 1 (WDW147)
- Figure 3-25 Flowing bottomhole pressure calibration for the Frio E and F Sand - Sealed Fault Case 1 at a reference depth of 6,548 feet bgl in ExxonMobil Wells
- Figure 3-26 Flowing bottomhole pressure calibration for the Frio E and F Sand - Open Fault Case 2 at a reference depth of 6,548 feet bgl at ExxonMobil's Wells
- Figure 3-27 Maximum Operational Plume (MF=3.8) at year-end 2017 for the Frio E&F Sand, Case 1 - Sealed Fault A-A' Case
- Figure 3-28 Maximum Operational Plume (MF=3.8) at year-end 2050 for the Frio E&F Sand, Case 1 - Sealed Fault A-A' Case
- Figure 3-29 Maximum Operational Plume (MF=3.8) at year-end 2017 for the Frio A/B/C Sand, Case 1 - Sealed Fault A-A' Case

- Figure 3-30 Maximum Operational Plume (MF=3.8) at year-end 2050 for the Frio A/B/C Sand, Case 1 - Sealed Fault A-A' Case
- Figure 3-31 Maximum Operational Plume (MF=3.8) at year-end 2017 for the Frio E&F Sand, Case 2 - Open Fault Case
- Figure 3-32 Maximum Operational Plume (MF=3.8) at year-end 2050 for the Frio E&F Sand, Case 2 - Open Fault Case
- Figure 3-33 Maximum Operational Plume (MF=3.8) at year-end 2017 for the Frio A/B/C Sand, Case 2 - Open Fault Case
- Figure 3-34 Maximum Operational Plume (MF=3.8) at year-end 2050 for the Frio A/B/C Sand, Case 2 - Open Fault Case
- Figure 3-35 Modeled upward permeation of injectate and formation brine above the Frio E and F Sand - Sealed Fault Case 1 at Plant Well 1 (WDW147)
- Figure 3-36 Pressure Contour Plot in the Frio A/B/C Sand - Case 1 – Sealed Fault Case at Year-end 2017 with Historical Injection
- Figure 3-37 Pressure Contour Plot in the Frio A/B/C Sand - Case 1 – Sealed Fault Case at Year-end 2050 w/Projected Injection - 750 gpm into Plant Well No. 2 (WDW-319)
- Figure 3-38 Modeled pressure increase graph at a rate of 750 gpm in the Frio A/B/C Sand - Sealed Fault Case 1 at a reference depth of 6,820.5 feet bgl in Plant Well 2 (WDW319)
- Figure 3-39 Pressure Contour Plot in the Frio E&F Sand - Case 1 – Sealed Fault Case at Year-end 2017 with Historical Injection
- Figure 3-40 Pressure Contour Plot in the Frio E&F Sand - Case 1 – Sealed Fault Case at Year-end 2050 w/Projected Injection - 750 gpm into Plant Well No. 1 (WDW-147)
- Figure 3-41 Modeled pressure increase graph at a rate of 750 gpm in the Frio E and F Sand - Sealed Fault Case 1 at a reference depth of 6,548 feet bgl in Plant Well 1 (WDW147)

- Figure 3-42 Pressure Contour Plot in the Frio A/B/C Sand - Case 2 – Open Fault Case at Year-end 2017 with Historical Injection
- Figure 3-43 Pressure Contour Plot in the Frio A/B/C Sand - Case 2 – Open Fault Case at Year-end 2050 w/Projected Injection - 750 gpm into Plant Well No. 2 (WDW-319)
- Figure 3-44 Modeled pressure increase graph at a rate of 750 gpm in the Frio A/B/C Sand - Open Fault Case 2 at a reference depth of 6,820.5 feet bgl in Plant Well 2 (WDW319)
- Figure 3-45 Pressure Contour Plot in the Frio E&F Sand - Case 2 – Open Fault Case at Year-end 2017 with Historical Injection
- Figure 3-46 Pressure Contour Plot in the Frio E&F Sand - Case 2 – Open Fault Case at Year-end 2050 w/Projected Injection - 750 gpm into Plant Well No. 1 (WDW-147)
- Figure 3-47 Modeled pressure increase graph at a rate of 750 gpm in the Frio E and F Sand - Open Fault Case 2 at a reference depth of 6,548 feet bgl in Plant Well 1 (WDW147)
- Figure 3-48 Fluid specific gravity as a function of concentration reduction factor within the Low Specific Gravity Plume
- Figure 3-49 Calculated drift velocity as a function of concentration reduction factor within the Low Specific Gravity Plume
- Figure 3-50 Relationship between concentration reduction factor and plume drift potential in the Low Specific Gravity Plume
- Figure 3-51 Low Specific Gravity Plume generated with a cumulative injection volume from 2006 of 3.945 billion gallons using a maximum dispersivity characteristic of movement to Clinton Dome of 216 feet
- Figure 3-52 Schematic cross section illustrating the area available for low specific gravity waste
- Figure 3-53 Sand thickness in the Frio E&F Sand available for waste above the structural spill point contour on the up-thrown (high) side of Fault “a”

- Figure 3-54 Sand thickness in the Frio E&F Sand available for waste above the structural spill point contour on the down-thrown (low) side of Fault “a”
- Figure 3-55 Computation of the available volume in the Frio E&F sand above the structural spill point contour on the up-thrown (high) side of Fault “a” using the horizontal slice method
- Figure 3-56 Computation of the available volume in the Frio E&F sand above the structural spill point contour on the down-thrown (low) side of Fault “a” in Segment A using the horizontal slice method
- Figure 3-57 Computation of the available volume in the Frio E&F sand above the structural spill point contour on the down-thrown (low) side of Fault “a” in Segment B using the horizontal slice method
- Figure 3-58 Sand thickness in the Frio A&B Sand available for waste above the structural spill point contour on the up-thrown (high) side of Fault “a”
- Figure 3-59 Sand thickness in the Frio A&B Sand available for waste above the structural spill point contour on the down-thrown (low) side of Fault “a”
- Figure 3-60 Computation of the available volume in the Frio A&B sand above the structural spill point contour on the up-thrown (high) side of Fault “a” using the horizontal slice method
- Figure 3-61 Computation of the available volume in the Frio A&B sand above the structural spill point contour on the down-thrown (low) side of Fault “a” in Segment A using the horizontal slice method
- Figure 3-62 Computation of the available volume in the Frio A&B sand above the structural spill point contour on the down-thrown (low) side of Fault “a” in Segment B using the horizontal slice method
- Figure 3-63 Sand thickness in the Frio C Sand available for waste above the structural spill point contour on the up-thrown (high) side of Fault “a”
- Figure 3-64 Sand thickness in the Frio C Sand available for waste above the structural spill point contour on the down-thrown (low) side of Fault “a”

- Figure 3-65 Computation of the available volume in the Frio C sand above the structural spill point contour on the up-thrown (high) side of Fault “a” using the horizontal slice method
- Figure 3-66 Computation of the available volume in the Frio C sand above the structural spill point contour on the down-thrown (low) side of Fault “a” in Segment A using the horizontal slice method
- Figure 3-67 Computation of the available volume in the Frio C sand above the structural spill point contour on the down-thrown (low) side of Fault “a” in Segment B using the horizontal slice method
- Figure 3-68 Sand thickness in the Frio D Sand available for waste above the structural spill point contour of –5,700 feet msl
- Figure 3-69 Sand thickness in the Frio E&F Sand available for waste above the structural spill point contour of –5,700 feet msl in the Frio D Sand
- Figure 3-70 Computation of the available volume in the Frio D sand above the –5,700 foot contour using the horizontal slice method
- Figure 3-71 Computation of the available volume in the Frio E&F sand above the –5,700-foot contour using the horizontal slice method
- Figure 3-72 DuPont 10,000-Year Waste Plume Model results at year-end 2050 and at the end of the 200-year evaluation time period – High Specific Gravity Plume
- Figure 3-73 Composite results of the Long-term Waste Plume modeling
- Figure 3-74 Long-term plumes on the top of the Frio E&F Sand Structure Map
- Figure 3-75 Long-term plumes on the Frio E&F Sand Isopach Map
- Figure 3-76 Long-term plumes on the Frio A/B Sand Isopach Map
- Figure 3-77 Long-term plumes on the Frio C Sand Isopach Map
- Figure 4-1 Cone of Influence Allowable Buildup Pressure and the Modeled Pressure Profile Case 1 – Sealed Fault A Case in the Frio E and F Sand Injection Interval at Year-end 2050 with 750 gpm into Plant Well No. 1 (WDW147).

- Figure 4-2 Cone of Influence Allowable Buildup Pressure and the Modeled Pressure Profile Case 1 – Sealed Fault A Case in the Frio A/B/C Sand Injection Interval at Year-end 2050 with 750 gpm into Plant Well No. 2 (WDW319)
- Figure 4-3 Cone of Influence Allowable Buildup Pressure and the Modeled Pressure Increase Profile Case 1 – Open Fault Case in the Frio E&F Sand Injection Interval at Year-end 2050 with maximum injection (750 gpm) into Injection Well No. 1 (WDW147).
- Figure 4-4 Cone of Influence Allowable Buildup Pressure and the Modeled Pressure Profile Case 2 – Open Fault A Case in the Frio A/B/C Sand Injection Interval at Year-end 2050 with 750 gpm into Plant Well No. 2 (WDW319).
- Figure 4-5 Artificial Penetrations in the 2.5-mile Radius Area of Review and Extended Area of Review and Plumes
- Figure 4-6 Operational and Long-Term Waste Plume Track for the Frio A/B/C Sand Injection Interval
- Figure 4-7 Clinton Dome Detailed Artificial Penetration Location Map
- Figure 5-1 Plant Well No. 1 (WDW147) Completion Schematic
- Figure 5-2 Plant Well No. 2 (WDW319) Completion Schematic
- Figure 6-1 Location of Waste Treatment, Storage and Disposal Facilities
- Figure 6-2 Waste Storage and Pre-Injection Treatment System
- Figure 6-3 Time-series graph of daily and three-whole calendar month volume weighted average specific gravity measured at 20 °F (January 2001 through December 2018)

MASTER LIST OF TABLES

Table 2-1	Critical Pressure Buildup Needed to Induce Seismicity
Table 2-2	Typical Sedimentary Shale Compositions
Table 2-3	Average X-Ray Diffraction Results - Lower Frio Formation
Table 2-4	Chemical Analysis of the Lower Frio Formation Fluids
Table 2-5	Calculated Fracture Gradients and Fracture Pressures
Table 3-1	Model Input Parameters – Operational Pressure Model
Table 3-2	Frio Injection Interval Sand Thicknesses Used in the Operational Plume Modeling and Post-Operational Plume Modeling
Table 3-3	Injection/Falloff Tests – Measured Reservoir Transmissibilities – Frio A/B/C Sand Injection Interval and Frio E&F Sand Injection Interval
Table 3-4	Shale Core Vertical Permeabilities – Arkema, Plant Well 2 (WDW230)
Table 3-5	Frio Injection Interval Sands – Modeled Porosities.
Table 3-6	Operational Model Fluid Properties Summary.
Table 3-7	Calculation of Lower Frio Sand Multiplying Factor for Input into DuPont Basic Plume Model
Table 3-8	Frio Injection Interval Sands – Calculated Gaussian and Modeled Multiplying Factors – Operational DuPont Basic Plume Model.
Table 3-9	Modeled Free Water and Effective Shale Diffusivities for the Constituents of Concern
Table 3-10	Concentration Reduction Factors and Molecular Diffusion Critical Constituent Parameters.
Table 3-11	Modeled Class I and Class II Lower Frio Injection Wells – Completion Histories
Table 3-12	Distances Between Injection Wells in the Operational Models.
Table 3-13	Projected Cumulative Injection Rates Through Year-End 2050 in the Frio A/B/C Sand.

Table 3-14	Projected Cumulative Injection Rates Through Year-End 2050 in the Frio E&F Sand.
Table 3-15	Modeled Nominal Plume Diameters – DuPont Basic Plume Model.
Table 3-16	Annual Model Predicted Formation Pressures in the Frio Injection Interval Sands.
Table 3-17	10,000 Year Waste Plume Model Inputs – Low Specific Gravity Long-term Model Inputs
Table 3-18	DuPont 10,000 Year Waste Plume Model Inputs – High Specific Gravity Long-term Model Inputs
Table 3-19	Relative Concentration Reduction Versus Fluid Density
Table 3-20	Determination of Plume Drift Rate for Specific Plume Points
Table 3-21	Available Closure Volumes at Clinton Dome
Table 3-22	Available Closure Volumes at Clinton Dome – Sensitivity Case
Table 4-1	Parameters used in Calculating the Cone of Influence
Table 4-2	Maximum Pressure Increases at 2.5-mile Radius from Sasol Chemicals (USA), LLC, Greens Bayou Plant Wells Nos. 1 (WDW147) and 2 (WDW319)
Table 4-3a	Artificial Penetrations in the 2.5-mile Radius Area of Review.
Table 4-3b	Artificial Penetrations in the Extended Area of Review (Operational Plume)
Table 4-4	Artificial Penetrations within the Modeled Long-term Plume Track
Table 4-5	Molecular Diffusion Transport Distances
Table 5-1	Casing and Tubing Dimensions and Parameters – Plant Well No. 1 (WDW147)
Table 5-2	Cementing Data – Plant Well No. 1 (WDW147)
Table 5-3	Casing and Tubing Dimensions and Parameters – Plant Well No. 2 (WDW319)
Table 5-4	Cementing Data – Plant Well No. 2 (WDW319)
Table 5-5	Class I Injection Chemicals and Corrosion Effects
Table 6-1	Waste Management Information

Table 6-2	Average and Maximum Rates of Injection at the Sasol Chemicals (USA), LLC Greens Bayou Plant
Table 6-3	Injection Well Checklist
Table 6-4	Modeled Maximum Pressure Increase at the Injection Wells
Table 6-5	Modeled Inputs for the Annual Testing Demonstration

MASTER LIST OF APPENDICES

Appendix 1-1	Typical Waste Stream Well Feed Composition and Recent Waste Stream Analysis (2018)
Appendix 1-2	Approval Letters for Hazardous Waste Disposal Restrictions Petition Exemptions Sasol Chemicals (USA), LLC Greens Bayou Plant
Appendix 1-3	Current Texas Commission on Environmental Quality - Underground Injection Control Permits
Appendix 1-4	Landowner and Mineral Owner Information
Appendix 2-1	Cambe Regional Structure Map
Appendix 2-2	Listing of Earthquake Data
Appendix 2-3	Annotated Logs Injection Well Logs WDW147 and WDW319
Appendix 2-4	Annotated Cross Section Well Logs
Appendix 2-5	Detailed Clinton Dome Cross Sections and Logs
Appendix 2-6	Detailed Stratigraphic Correlations of the Injection Interval Sands in the 2.5-Mile Radius Area of Review
Appendix 2-7	Stratigraphic Correlation of the Injection Interval Sands to Clinton Dome
Appendix 2-8	Detailed Clinton Dome Structure Maps
Appendix 2-9	Detailed Clinton Dome Isopach Maps
Appendix 2-10	Field Structure Maps – Miocene 3,800' Sand
Appendix 2-11	Determination of the Base of the Lowermost USDW
Appendix 2-12	2018 Tabulation of Water Wells
Appendix 3-1	DuPont Basic Plume Model
Appendix 3-2	DuPont Multilayer Pressure Model

Appendix 3-3	DuPont Vertical Permeation Model
Appendix 3-4	DuPont Molecular Diffusion Model
Appendix 3-5	DuPont 10,000-Year Waste Plume Model
Appendix 3-6	Determination of Model Input Data
Appendix 3-7	DuPont Multilayer Pressure Model Calibration Input and Output Files
Appendix 3-8	DuPont Multilayer Pressure Model Projected Year End 2050 Model Input and Output Files
Appendix 3-9	DuPont Vertical Permeation Model Projected Year End 2050 Model Input and Output Files – Projected Vertical Permeation Files
Appendix 3-10	DuPont Basic Plume Model Projected Year End 2050 Model Input and Output Files – Projected Plume Files
Appendix 3-11	DuPont 10,000 Year Model Long-term Input and Output Files
Appendix 4-1	Artificial Penetration Protocol
Appendix 4-2	Artificial Penetration Well Records in the Area of Review
Appendix 4-3	Artificial Penetration Well Records in the Extended Area of Review
Appendix 4-4	Artificial Penetration Well Records in the Long-term Plume Track
Appendix 5-1	Current Texas Commission on Environmental Quality Underground Injection Control Permits
Appendix 5-2	Cement and Annular Volume Calculations
Appendix 5-3	Plant Well Deviation Surveys
Appendix 5-4	Plant Well Tubular Stress Calculations
Appendix 6-1	Sasol Chemicals (USA), LLC 2018 Waste Stream Analysis Report
Appendix 6-2	Specific Gravity Measurement Procedures

Appendix 6-3	Waste Stream Specific Gravity Compliance Program
Appendix 6-4	Annual Well Pressure Transient Testing and Reporting Program
Appendix 7-1	Plant Well 1 (WDW147) - 2018 Annulus Pressure Test Chart
Appendix 7-2	Plant Well 1 (WDW147) – 2018 Radioactive Tracer Log
Appendix 7-3	Plant Well 2 (WDW319) – 2018 Annulus Pressure Test Chart
Appendix 7-4	Plant Well 2 (WDW319) - 2018 Radioactive Tracer Log